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(54) Speech recognition system with improved rejection of words and sounds not contained in the system vocabulary

Spracherkennungseinrichtung mit verbesserter Ausschliessung von Wörtern und Tönen welche nicht im Vokabular enthalten sind

Système de reconnaissance de la parole avec rejet des mots et des sons qui ne sont pas compris dans le vocabulaire du système

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(56) References cited:
EP-A- 0 237 934
EP-A- 0 241 163
EP-A- 0 314 908
EP-A- 0 523 347
GB-A- 2 075 312
US-A- 4 239 936
US-A- 4 410 763

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Description

Background of the Invention

[0001] The invention relates to computer speech recognition, particularly to the recognition of spoken computer commands. When a spoken command is recognized, the computer performs one or more functions associated with the command.

[0002] In general, a speech recognition apparatus consists of an acoustic processor and a stored set of acoustic models. The acoustic processor measures sound features of an utterance. Each acoustic model represents the acoustic features of an utterance of one or more words associated with the model. The sound features of the utterance are compared to each acoustic model to produce a match score. The match score for an utterance and an acoustic model is an estimate of the closeness of the sound features of the utterance to the acoustic model.

[0003] The word or words associated with the acoustic model having the best match score may be selected as the recognition result. Alternatively, the acoustic match score may be combined with other match scores, such as additional acoustic match scores and language model match scores. The word or words associated with the acoustic model or models having the best combined match score may be selected as the recognition result.

[0004] For command and control applications, the speech recognition apparatus preferably recognizes an uttered command, and the computer system then immediately executes the command to perform a function associated with the recognized command. For this purpose, the command associated with the acoustic model having the best match score may be selected as the recognition result.

[0005] A serious problem with such systems, however, is that inadvertent sounds such as coughs, sighs, or spoken words not intended for recognition can be misrecognized as valid commands. The computer system then immediately executes the misrecognized commands to perform the associated functions with unintended consequences.

[0006] US-A-4,239,936 discloses a speech recognition system in which ambient noise intensity is measured in parallel to the input speech signals, with any recognition result assigned to the input speech signal being rejected when the intensity of the noise exceeds a predetermined standard value.

Summary of the Invention

[0007] It is an object of the invention to provide a speech recognition apparatus and method which has a high likelihood of rejecting acoustic matches to inadvertent sounds or words spoken but not intended for the speech recognizer.

[0008] It is another object of the invention to provide a speech recognition apparatus and method which identifies the acoustic model which is best matched to a sound, and which has a high likelihood of rejecting the best matched acoustic model if the sound is inadvertent or not intended for the speech recognizer, but which has a high likelihood of accepting the best matched acoustic model if the sound is a word or words intended for recognition.

[0009] A speech recognition apparatus according to the invention comprises an acoustic processor for measuring the value of at least one feature of each of a sequence of at least two sounds. The acoustic processor measures the value of the feature of each sound during each of a series of successive time intervals to produce a series of feature signals representing the feature values of the sound. Means are also provided for storing a set of acoustic command models. Each acoustic command model represents one or more series of acoustic feature values representing an utterance of a command associated with the acoustic command model.

[0010] A match score processor generates a match score for each sound and each of one or more acoustic command models from the set of acoustic command models. Each match score comprises an estimate of the closeness of a match between the acoustic command model and a series of feature signals corresponding to the sound. Means are provided for outputting a recognition signal corresponding to the command model having the best match score for a current sound if the best match score for the current sound is better than a recognition threshold score for the current sound. The recognition threshold for the current sound comprises (a) a first confidence score if the best match score for a prior sound was better than a recognition threshold for that prior sound, or (b) a second confidence score better than the first confidence score if the best match score for a prior sound was worse than the recognition threshold for that prior sound.

[0011] Preferably, the prior sound occurs immediately prior to the current sound.

[0012] A speech recognition apparatus according to the invention may further comprise means for storing at least one acoustic silence model representing one or more series of acoustic feature values representing the absence of a spoken utterance. The match score processor also generates a match score for each sound and the acoustic silence model. Each silence match score comprises an estimate of the closeness of a match between the acoustic silence model and a series of feature signals corresponding to the sound.

[0013] In this aspect of the invention, the recognition threshold for the current sound comprises the first confidence score (a1) if the match score for the prior sound and the acoustic silence model is better than a silence match threshold,

and if the prior sound has a duration exceeding a silence duration threshold, or (a2) if the match score for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was better than a recognition threshold for that next prior sound, or (a3) if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was better than a recognition threshold for that prior sound.

[0014] The recognition threshold for the current sound comprises the second confidence score better than the first confidence score (b1) if the match score for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was worse than the recognition threshold for that next prior sound, or (b2) if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was worse than the recognition threshold for that prior sound.

[0015] The recognition signal may be, for example, a command signal for calling a program associated with the command. In one aspect of the invention, the output means comprises a display, and the output means displays one or more words corresponding to the command model having the best match score for a current sound if the best match score for the current sound is better than the recognition threshold score for the current sound.

[0016] In another aspect of the invention, the output means outputs an unrecognizable-sound indication signal if the best match score for the current sound is worse than the recognition threshold score for the current sound. For example, the output means may display an unrecognizable-sound indicator if the best match score for the current sound is worse than the recognition threshold score for the current sound. The unrecognizable-sound indicator may comprise, for example, one or more question marks.

[0017] The acoustic processor in the speech recognition apparatus according to the invention may comprise, in part, a microphone. Each sound may be, for example, a vocal sound, and each command may comprise at least one word.

[0018] According to a further aspect of the invention, a speech recognition method as defined in claim 11 is provided.

[0019] Thus, according to the invention, acoustic match scores generally fall into three categories. When the best match score is better than a "good" confidence score, the word or words corresponding to the acoustic model having the best match score almost always correspond to the measured sounds. On the other hand, when the best match score is worse than a "poor" confidence score, the word corresponding to the acoustic model having the best match score almost never corresponds to the measured sounds. When the best match score is better than the "poor" confidence score but is worse than the "good" confidence score, the word corresponding to the acoustic model having the best match score has a high likelihood of corresponding to the measured sound when the previously recognized word was accepted as having a high likelihood of corresponding to the previous sound. When the best match score is better than the "poor" confidence score but is worse than the "good" confidence score, the word corresponding to the acoustic model having the best match score has a low likelihood of corresponding to the measured sound when the previously recognized word was rejected as having a low likelihood of corresponding to the previous sound. However, if there is sufficient intervening silence between a previously rejected word and the current word having the best match score better than the "poor" confidence score but worse than the "good" confidence score, then the current word is also accepted as having a high likelihood of corresponding to the measured current sound.

[0020] By adopting the confidence scores according to the invention, a speech recognition apparatus and method has a high likelihood of rejecting acoustic matches to inadvertent sounds or words spoken but not intended for the speech recognizer. That is, by adopting the confidence scores according to the invention, a speech recognition apparatus and method which identifies the acoustic model which is best matched to a sound has a high likelihood of rejecting the best matched acoustic model if the sound is inadvertent or not intended for the speech recognizer, and has a high likelihood of accepting the best matched acoustic model if the sound is a word or words intended for the speech recognizer.

Brief Description of the Drawing

[0021]

Figure 1 is a block diagram of an example of a speech recognition apparatus according to the invention.

Figure 2 schematically shows an example of an acoustic command model.

Figure 3 schematically shows an example of an acoustic silence model.

Figure 4 schematically shows an example of the acoustic silence model of Figure 3 concatenated onto the end of the acoustic command model of Figure 2.

Figure 5 schematically shows the states and possible transitions between states for the combined acoustic model of Figure 4 at each of a number of times t.

Figure 6 is a block diagram of an example of the acoustic processor of Figure 1.

Description of the Preferred Embodiments

[0022] Referring to Figure 1, the speech recognition apparatus according to the invention comprises an acoustic processor 10 for measuring the value of at least one feature of each of a sequence of at least two sounds. The acoustic processor 10 measures the value of the feature of each sound during each of a series of successive time intervals to produce a series of feature signals representing the feature values of the sound.

[0023] As described in more detail, below, the acoustic processor may, for example, measure the amplitude of each sound in one or more frequency bands during each of a series of ten-millisecond time intervals to produce a series of feature vector signals representing the amplitude values of the sound. If desired, the feature vector signals may be quantized by replacing each feature vector signal with a prototype vector signal, from a set of prototype vector signals, which is best matched to the feature vector signal. Each prototype vector signal has a label identifier, and so in this case the acoustic processor produces a series of label signals representing the feature values of the sound.

[0024] The speech recognition apparatus further comprises an acoustic command models store 12 for storing a set of acoustic command models. Each acoustic command model represents one or more series of acoustic feature values representing an utterance of a command associated with the acoustic command model.

[0025] The stored acoustic command models may be, for example, Markov models or other dynamic programming models. The parameters of the acoustic command models may be estimated from a known uttered training text by, for example, smoothing parameters obtained by the forward-backward algorithm. (See, for example, F. Jelinek. "Continuous Speech Recognition By Statistical Methods." Proceedings of the IEEE, Vol. 64, No. 4, April 1976, pages 532-556.)

[0026] Preferably, each acoustic command model represents a command spoken in isolation (that is, independent of the context of prior and subsequent utterances). Context-independent acoustic command models can be produced, for example, either manually from models of phonemes, or automatically, for example, by the method described by Lalit R. Bahl et al in U.S. Patent 4,759,068 entitled "Constructing Markov Models of Words From Multiple Utterances", or by any other known method of generating context-independent models.

[0027] Alternatively, context-dependent models may be produced from context-independent models by grouping utterances of a command into context-dependent categories. A context can be, for example, manually selected, or automatically selected by tagging each feature signal corresponding to a command with its context, and by grouping the feature signals according to their context to optimize a selected evaluation function. (See, for example, Lalit R. Bahl et al, "Apparatus and Method of Grouping Utterances of a Phoneme into Context-Dependent Categories Based on Sound-Similarity for Automatic Speech Recognition." U.S. Patent 5,195,167.)

[0028] Figure 2 schematically shows an example of a hypothetical acoustic command model. In this example, the acoustic command model comprises four states S1, S2, S3, and S4 illustrated in Figure 2 as dots. The model starts at the initial state S1 and terminates at the final state S4. The dashed null transitions correspond to no acoustic feature signal output by the acoustic processor 10. To each solid line transition, there corresponds an output probability distribution over either feature vector signals or label signals produced by the acoustic processor 10. For each state of the model, there corresponds a probability distribution over the transitions out of that state.

[0029] Returning to Figure 1, the speech recognition apparatus further comprises a match score processor 14 for generating a match score for each sound and each of one or more acoustic command models from the set of acoustic command models in acoustic command models store 12. Each match score comprises an estimate of the closeness of a match between the acoustic command model and a series of feature signals from acoustic processor 10 corresponding to the sound.

[0030] A recognition threshold comparator and output 16 outputs a recognition signal corresponding to the command model from acoustic command models store 12 having the best match score for a current sound if the best match score for the current sound is better than a recognition threshold score for the current sound. The recognition threshold for the current sound comprises a first confidence score from confidence scores store 18 if the best match score for a prior sound was better than a recognition threshold for that prior sound. The recognition threshold for the current sound comprises a second confidence score from confidence scores store 18, better than the first confidence score, if the best match score for a prior sound was worse than the recognition threshold for that prior sound.

[0031] The speech recognition apparatus may further comprise an acoustic silence model store 20 for storing at least one acoustic silence model representing one or more series of acoustic feature values representing the absence

of a spoken utterance. The acoustic silence model may be, for example, a Markov model or other dynamic programming model. The parameters of the acoustic silence model may be estimated from a known uttered training text by, for example, smoothing parameters obtained by the forward-backward algorithm, in the same manner as for the acoustic command models.

[0032] Figure 3 schematically shows an example of an acoustic silence model. The model starts in the initial state S4 and terminates in the final state S10. The dashed null transitions correspond to no acoustic feature signal output. To each solid line transition there corresponds an output probability distribution over the feature signals (for example, feature vector signals or label signals) produced by the acoustic processor 10. For each state S4 through S10, there corresponds a probability distribution over the transitions out of that state.

[0033] Returning to Figure 1, the match score processor 14 generates a match score for each sound and the acoustic silence model in acoustic silence model store 20. Each match score with the acoustic silence model comprises an estimate of the closeness of a match between the acoustic silence model and a series of feature signals corresponding to the sound.

[0034] In this variation of the invention, the recognition threshold utilized by recognition threshold comparator and output 16 comprises the first confidence score if the match score for the prior sound and the acoustic silence model is better than a silence match threshold obtained from silence match and duration thresholds store 22, and if the prior sound has a duration exceeding a silence duration threshold stored in silence match and duration thresholds store 22. Alternatively, the recognition threshold for the current sound comprises the first confidence score if the match score for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was better than a recognition threshold for that next prior sound. Finally, the recognition threshold for the current sound comprises the first confidence score if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was better than a recognition threshold for that prior sound.

[0035] In this embodiment of the invention, the recognition threshold for the current sound comprises the second confidence score better than the first confidence score from confidence scores store 18 if the match score from match score processor 18 for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was worse than the recognition threshold for that next prior sound. Alternatively, the recognition threshold for the current sound comprises the second confidence score better than the first confidence score if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was worse than the recognition threshold for that prior sound.

[0036] In order to generate a match score for each sound and each of one or more acoustic command models from the set of acoustic command models in acoustic command models store 12, and in order to generate a match score for each sound and the acoustic silence model in acoustic silence model store 20, the acoustic silence model of Figure 3 may be concatenated onto the end of the acoustic command model of Figure 2, as shown in Figure 4. The combined model starts in the initial state S1, and terminates in the final state S10.

[0037] The states S1 through S10 and the allowable transitions between the states for the combined acoustic model of Figure 4 at each of a number of times t are schematically shown in Figure 5. For each time interval between t=n-1 and t=n , the acoustic processor produces a feature signal X_n.

[0038] For each state of the combined model shown in Figure 4, the conditional probability $P(s_t=S\sigma|X_1...X_t)$ that state s_t equals state $S\sigma$ at time t given the occurrence of feature signals X_1 through X_t produced by the acoustic processor 10 at times 1 through t, respectively, is obtained by Equations 1 through 10.

$$P(s_t = S1|X_1...X_t) = [P(s_{t-1} = S1)\ P(s_t = S1|s_{t-1} = S1)\ P(X_t|s_t = S1, s_{t-1} = S1)] \quad [1]$$

$$P(s_t=S2|X_1...X_t) = [P(s_{t-1} = S1)\ P(s_t =S2|s_{t-1} = S1)\ P(X_t|s_t = S2, s_{t-1} = S1)] + P(s_t = S1)\ P(s_t = S2|s_t = S1) + [P(s_{t-1} = S2)\ P(s_t = S2|s_{t-1} = S2)\ P(X_t|s_t = S2, s_{t-1} = S2)] \quad [2]$$

$$P(s_t = S3|X_1...X_t) = [P(s_{t-1} = S2)\ P(s_t = S3|s_{t-1} = S2)\ P(X_t|s_t = S3,\ s_{t-1} = S2)] + P(s_t = S2)\ P(s_t = S3|s_t = S2) + [P(s_{t-1} = S3)\ P(s_t = S3|s_{t-1} = S3)\ P(X_t|s_t = S3,\ s_{t-1} = S3)] \quad [3]$$

$$P(s_t = S4|X_1...X_t) = [P(s_{t-1} = S3)\ P(s_t = S4|s_{t-1} = S3)\ P(X_t|s_t = S4,\ s_{t-1} = S3)] + P(s_t = S3)\ P(s_t = S4|s_t = S3) \quad [4]$$

$$P(s_t = S5|X_1...X_t) = [P(s_{t-1} = S4)\ P(s_t = S5|s_{t-1} = S4)\ P(X_t|s_t = S5,\ s_{t-1} = S4)] + [P(s_{t-1} = S5)\ P(s_t = S5|s_{t-1} = S5)\ P(X_t|s_t = S5,\ s_{t-1} = S5)] \quad [5]$$

$$P(s_t = S6|X_1...X_t) = [P(s_{t-1} = S5)\ P(s_t = S6|s_{t-1} = S5)\ P(X_t|s_t = S6,\ s_{t-1} = S5)] + [P(s_{t-1} = S6)\ P(s_t = S6|s_{t-1} = S6)\ P(X_t|s_t = S6,\ s_{t-1} = S6)] \quad [6]$$

$$P(s_t = S7|X_1...X_t) = [P(s_{t-1} = S6)\ P(s_t = S7|s_{t-1} = S6)\ P(X_t|s_t = S7,\ s_{t-1} = S6)] + P(s_{t-1} = S7)\ P(s_t = S7|s_{t-1} = S7)\ P(X_t|s_t = S7,\ s_{t-1} = S7)] \quad [7]$$

$$P(s_t = S8|X_1...X_t) = [P(s_{t-1} = S4)\ P(s_t = S8|s_{t-1} = S4)\ P(X_t|s_t = S8,\ s_{t-1} = S4)] \quad [8]$$

$$P(s_t = S9|X_1...X_t) = [P(s_{t-1} = S8)\ P(s_t = S9|s_{t-1} = S8)\ P(X_t|s_t = S9,\ s_{t-1} = S8)] \quad [9]$$

$$P(s_t = S10|X_1...X_t) = P(s_t = S4)\ P(s_t = S10|s_t = S4) + P(s_t = S8)\ P(s_t = S10|s_t = S8) + P(s_t = S9)\ P(s_t = S10|s_t = S9) + [P(s_{t-1} = S7)\ P(s_t = S10|s_{t-1} = S7)\ P(X_t|s_t = S10,\ s_{t-1} = S7)] + [P(s_{t-1} = S9)\ P(s_t = S10|s_{t-1} = S9)\ P(X_t|s_t = S10,\ s_{t-1} = S9)] \quad [10]$$

[0039] In order to normalize the conditional state probabilities to account for the different numbers of feature signals ($X_1...X_t$) at different times t, a normalized state output score Q for a state σ at time t can be given by Equation 11.

$$Q(\sigma, t) = \frac{P(s_t = S\sigma | X_1...X_t)}{\prod_{i=1}^{t} P(X_i)} \quad [11]$$

[0040] Estimated values for the conditional probabilities $P(s_t = S\sigma|X_1...X_t)$ of the states (in this example, states S1 through S10) can be obtained from Equations 1 through 10 by using the values of the transition probability parameters and the output probability parameters of the acoustic command models and acoustic silence model.

[0041] Estimated values for the normalized state output score Q can be obtained from Equation 11 by estimating the probability $P(X_i)$ of each observed feature signal X_i as the product of the conditional probability $P(X_i|X_{i-1})$ of feature

signal X_i given the immediately prior occurrence of feature signal X_{i-1}, multiplied by the probability $P(X_{i-1})$ of occurrence of the feature signal X_{i-1}. The value of $P(X_i|X_{i-1})\ P(X_{i-1})$ for all feature signals X_i and X_{i-1} may be estimated by counting the occurrences of feature signals generated from a training text according to Equation 12.

$$P(X_i|X_{i-1})P(X_{i-1}) = \frac{N(X_i,X_{i-1})}{N(X_{i-1})}\ \frac{N(X_{i-1})}{N} = \frac{N(X_i,X_{i-1})}{N} \quad [12]$$

[0042] In Equation 12, $N(X_i, X_{i-1})$ is the number of occurrences of the feature signal X_i immediately preceded by the feature signal X_{i-1} generated by the utterance of the training script, and N is the total number of feature signals generated by the utterance of the training script.

[0043] From Equation 11, above, normalized state output scores Q(S4, t) and Q(S10, t) can be obtained for states S4 and S10 of the combined model of Figure 4. State S4 is the last state of the command model and is the first state of the silence model. State S10 is the last state of the silence model.

[0044] In one example of the invention, a match score for a sound and the acoustic silence model at time t may be given by the ratio of the normalized state output score Q[S10,t] for state S10 divided by the normalized state output score Q[S4,t] for state S4 as shown in Equation 13.

$$\text{Silence Start Match Score} = \frac{Q[S10,t]}{Q[S4,t]} \quad [13]$$

[0045] The time $t=t_{start}$ at which the match score for the sound and the acoustic silence model (Equation 13) first exceeds a silence match threshold may be considered to be the beginning of an interval of silence. The silence match threshold is a tuning parameter which may be adjusted by the user. A silence match threshold of 10^{15} has been found to produce good results.

[0046] The end of the interval of silence may, for example, be determined by evaluating the ratio of the normalized state output score Q[S10,t] for state S10 at time t divided by the maximum value obtained for the normalized state output score $Q_{max}[S10, t_{start}...t]$ for state S10 over time intervals t_{start} through t.

$$\text{Silence End Match Score} = \frac{Q[S10,t]}{Q_{max}[S10,t_{start}...t]} \quad [14]$$

[0047] The time $t = t_{end}$ at which the value of the silence end match score of Equation 14 first falls below the value of a silence end threshold may be considered to be the end of the interval of silence. The value of the silence end threshold is a tuning parameter which can be adjusted by the user. A value of 10^{-25} has been found to provide good results.

[0048] If the match score for the sound and the acoustic silence model as given by Equation 13 is better than the silence match threshold, then the silence is considered to have started the first time t_{start} at which the ratio of Equation 13 exceeded the silence match threshold. The silence is considered to have ended at the first time t_{end} at which the ratio of Equation 14 is less than the associated tuning parameter. The duration of the silence is then $(t_{end} - t_{start})$.

[0049] For the purpose of deciding whether the recognition threshold should be the first confidence score or the second confidence score, the silence duration threshold stored in silence match and duration thresholds store 22 is a tuning parameter which is adjustable by the user. A silence duration threshold of, for example, 25 centiseconds has been found to provide good results.

[0050] The match score for each sound and an acoustic command model corresponding to states S1 through S4 of Figures 2 and 4 may be obtained as follows. If the ratio of Equation 13 does not exceed the silence match threshold prior to the time t_{end}, the match score for each sound and the acoustic command model corresponding to states S1 through S4 of Figures 2 and 4 may be given by the maximum normalized state output score $Q_{max}[S10, t'_{end}...t_{end}]$ for state S10 over time intervals t'_{end} through t_{end}, where t'_{end} is the end of the preceding sound or silence, and where t_{end} is the end of the current sound or silence. Alternatively, the match score for each sound and the acoustic command model may be given by the sum of the normalized state output scores $Q[S10,t]$ for state S10 over time intervals t'_{end} through t_{end}. However, if the ratio of Equation 13 exceeds the silence match threshold prior to the time t_{end}, then the match score for the sound and the acoustic command model may be given by the normalized state output score $Q[S4, t_{start}]$ for state S4 at time t_{start}. Alternatively, the match score for each sound and the acoustic command model may be

given by the sum of the normalized state output scores $Q[S4,t]$ for state S4 over time intervals t'_{end} through t_{start}.

[0051] The first confidence score and the second confidence score for the recognition threshold are tuning parameters which may be adjusted by the user. The first and second confidence scores may be generated, for example, as follows.

[0052] A training script comprising in-vocabulary command words represented by stored acoustic command models, and also comprising out-of-vocabulary words which are not represented by stored acoustic command models is uttered by one or more speakers. Using the speech recognition apparatus according to the invention, but without a recognition threshold, a series of recognized words are generated as being best matched to the uttered, known training script. Each word or command output by the speech recognition apparatus has an associated match score.,

[0053] By comparing the command words in the known training script with the recognized words output by the speech recognition apparatus, correctly recognized words and misrecognized words can be identified. The first confidence score may, for example, be the best match score which is worse than the match scores of 99% to 100% of the correctly recognized words. The second confidence score may be, for example, the worst match score which is better than the match scores of, for example, 99% to 100% of the misrecognized words in the training script.

[0054] The recognition signal which is output by the recognition threshold comparator and output 16 may comprise a command signal for calling a program associated with the command. For example, the command signal may simulate the manual entry of keystrokes corresponding to a command. Alternatively, the command signal may be an application program interface call.

[0055] The recognition threshold comparator and output 16 may comprise a display, such as a cathode ray tube, a liquid crystal display, or a printer. The recognition threshold comparator and output 16 may display one or more words corresponding to the command model having the best match score for a current sound if the best match score for the current sound is better than the recognition threshold score for the current sound.

[0056] The output means 16 may optionally output an unrecognizable-sound signal if the best match score for the current sound is worse than the recognition threshold score for the current sound. For example, the output 16 may display an unrecognizable-sound indicator if the best match score for the current sound is worse than the recognition threshold score for the current sound. The unrecognizable-sound indicator may comprise one or more displayed question marks.

[0057] Each sound measured by the acoustic processor 10 may be a vocal sound or some other sound. Each command associated with an acoustic command model preferably comprises at least one word.

[0058] At the beginning of a speech recognition session, the recognition threshold may be initialized at either the first confidence score or the second confidence score. Preferably, however, the recognition threshold for the current sound is initialized at the first confidence score at the beginning of a speech recognition session.

[0059] The speech recognition apparatus according to the present invention may be used with any existing speech recognizer, such as the IBM Speech Server Series (trademark) product. The match score processor 14 and the recognition threshold comparator and output 16 may be, for example, suitably programmed special purpose or general purpose digital processors. The acoustic command models store 12, the confidence scores store 18, the acoustic silence model store 20, and the silence match and duration thresholds store 22 may comprise, for example, electronic readable computer memory.

[0060] One example of the acoustic processor 10 of Figure 3 is shown in Figure 6. The acoustic processor comprises a microphone 24 for generating an analog electrical signal corresponding to the utterance. The analog electrical signal from microphone 24 is converted to a digital electrical signal by analog to digital converter 26. For this purpose, the analog signal may be sampled, for example, at a rate of twenty kilohertz by the analog to digital converter 26.

[0061] A window generator 28 obtains, for example, a twenty millisecond duration sample of the digital signal from analog to digital converter 26 every ten milliseconds (one centisecond). Each twenty millisecond sample of the digital signal is analyzed by spectrum analyzer 30 in order to obtain the amplitude of the digital signal sample in each of, for example, twenty frequency bands. Preferably, spectrum analyzer 30 also generates a twenty-first dimension signal representing the total amplitude or total power of the twenty millisecond digital signal sample. The spectrum analyzer 30 may be, for example, a fast Fourier transform processor. Alternatively, it may be a bank of twenty band pass filters.

[0062] The twenty-one dimension vector signals produced by spectrum analyzer 30 may be adapted to remove background noise by an adaptive noise cancellation processor 32. Noise cancellation processor 32 subtracts a noise vector N(t) from the feature vector F(t) input into the noise cancellation processor to produce an output feature vector *F'(t)*. The noise cancellation processor 32 adapts to changing noise levels by periodically updating the noise vector N(t) whenever the prior feature vector F(t-1) is identified as noise or silence. The noise vector N(t) is updated according to the formula

$$N(t) = \frac{N(t\text{-}1)+k[F(t\text{-}1)-Fp(t\text{-}1)]}{(1+k)}, \qquad [15]$$

where N(t) is the noise vector at time t, N(t-1) is the noise vector at time (t-1), k is a fixed parameter of the adaptive noise cancellation model, $F(t\text{-}1)$ is the feature vector input into the noise cancellation processor 32 at time (t-1) and which represents noise or silence, and Fp(t-1) is one silence or noise prototype vector, from store 34, closest to feature vector $F(t\text{-}1)$.

[0063] The prior feature vector F(t-1) is recognized as noise or silence if either (a) the total energy of the vector is below a threshold, or (b) the closest prototype vector in adaptation prototype vector store 36 to the feature vector is a prototype representing noise or silence. For the purpose of the analysis of the total energy of the feature vector, the threshold may be, for example, the fifth percentile of all feature vectors (corresponding to both speech and silence) produced in the two seconds prior to the feature vector being evaluated.

[0064] After noise cancellation, the feature vector $F'(t)$ is normalized to adjust for variations in the loudness of the input speech by short term mean normalization processor 38. Normalization processor 38 normalizes the twenty-one dimension feature vector $F'(t)$ to produce a twenty dimension normalized malized feature vector X(t). The twenty-first dimension of the feature vector $F'(t)$, representing the total amplitude or total power, is discarded. Each component i of the normalized feature vector X(t) at time t may, for example, be given by the equation

$$X_i(t) = F'_i(t) - Z(t) \qquad [16]$$

in the logarithmic domain, where $F'_i(t)$ is the i-th component of the unnormalized vector at time t, and where Z(t) is a weighted mean of the components of $F'(t)$ and Z(t - 1) according to Equations 17 and 18:

$$Z(t) = 0.9Z(t\text{-}1)+0.1M(t) \qquad [17]$$

and where

$$M(t) = \frac{1}{20}\sum_i F'_i(t) \qquad [18]$$

[0065] The normalized twenty dimension feature vector X(t) may be further processed by an adaptive labeler 40 to adapt to variations in pronunciation of speech sounds. An adapted twenty dimension feature vector $X'(t)$ is generated by subtracting a twenty dimension adaptation vector A(t) from the twenty dimension feature vector X(t) provided to the input of the adaptive labeler 40. The adaptation vector A(t) at time t may, for example, be given by the formula

$$A(t) = \frac{A(t\text{-}1)+k[X(t\text{-}1)-Xp(t\text{-}1)]}{(1+k)}, \qquad [19]$$

where k is a fixed parameter of the adaptive labeling model, $X(t\text{-}1)$ is the normalized twenty dimension vector input to the adaptive labeler 40 at time (t-1), Xp(t-1) is the adaptation prototype vector (from adaptation prototype store 36) closest to the twenty dimension feature vector $X(t\text{-}1)$ at time (t-1), and A(t-1) is the adaptation vector at time (t-1).

[0066] The twenty dimension adapted feature vector signal $X'(t)$ from the adaptive labeler 40 is preferably provided to an auditory model 42. Auditory model 42 may, for example, provide a model of how the human auditory system perceives sound signals. An example of an auditory model is described in U.S. Patent 4,980,918 to Bahl et al entitled "Speech Recognition System with Efficient Storage and Rapid Assembly of Phonological Graphs".

[0067] Preferably, according to the present invention, for each frequency band i of the adapted feature vector signal $X'(t)$ at time t, the auditory model 42 calculates a new parameter $E_i(t)$ according to Equations 20 and 21:

$$E_i(t)=K_1 + K_2(X'_i(t))(N_i(t\text{-}1)) \qquad [20]$$

where

$$N_i(t)=K_3 \times N_i(t\text{-}1)\text{-}E_i(t\text{-}1) \qquad [21]$$

and where K_1, K_2, and K_3 are fixed parameters of the auditory model.

[0068] For each centisecond time interval, the output of the auditory model 42 is a modified twenty dimension feature vector signal. This feature vector is augmented by a twenty-first dimension having a value equal to the square root of the sum of the squares of the values of the other twenty dimensions.

[0069] For each centisecond time interval, a concatenator 44 preferably concatenates nine twenty-one dimension feature vectors representing the one current centisecond time interval, the four preceding centisecond time intervals, and the four following centisecond time intervals to form a single spliced vector of 189 dimensions. Each 189 dimension spliced vector is preferably multiplied in a rotator 46 by a rotation matrix to rotate the spliced vector and to reduce the spliced vector to fifty dimensions.

[0070] The rotation matrix used in rotator 46 may be obtained, for example, by classifying into M classes a set of 189 dimension spliced vectors obtained during a training session. The covariance matrix for all of the spliced vectors in the training set is multiplied by the inverse of the within-class covariance matrix for all of the spliced vectors in all M classes. The first fifty eigenvectors of the resulting matrix form the rotation matrix. (See, for example, "Vector Quantization Procedure For Speech Recognition Systems Using Discrete Parameter Phoneme-Based Markov Word Models" by L. R. Bahl, et al, IBM Technical Disclosure Bulletin, Volume 32, No. 7, December 1989, pages 320 and 321.)

[0071] Window generator 28, spectrum analyzer 30, adaptive noise cancellation processor 32, short term mean normalization processor 38, adaptive labeler 40, auditory model 42, concatenator 44, and rotator 46, may be suitably programmed special purpose or general purpose digital signal processors. Prototype stores 34 and 36 may be electronic computer memory of the types discussed above.

[0072] The prototype vectors in prototype store 34 may be obtained, for example, by clustering feature vector signals from a training set into a plurality of clusters, and then calculating the mean and standard deviation for each cluster to form the parameter values of the prototype vector. When the training script comprises a series of word-segment models (forming a model of a series of words), and each word-segment model comprises a series of elementary models having specified locations in the word-segment models, the feature vector signals may be clustered by specifying that each cluster corresponds to a single elementary model in a single location in a single word-segment model. Such a method is described in more detail in U.S. Patent Application Serial No. 730,714, filed on July 16, 1991, entitled "Fast Algorithm for Deriving Acoustic Prototypes for Automatic Speech Recognition."

[0073] Alternatively, all acoustic feature vectors generated by the utterance of a training text and which correspond to a given elementary model may be clustered by K-means Euclidean clustering or K-means Gaussian clustering, or both. Such a method is described, for example, by Bahl et al in U.S. Patent 5,182,773 entitled "Speaker-Independent Label Coding Apparatus".

Claims

1. A speech recognition apparatus comprising: an acoustic processor (10) for measuring the value of at least one feature of each of a sequence of at least two sounds, said acoustic processor (10) measuring the value of the feature of each sound during each of a series of successive time intervals to produce a series of feature signals representing the feature values of the sound;

means (12) for storing a set of acoustic command models, each acoustic command model representing one or more series of acoustic feature values representing an utterance of a command associated with the acoustic command model;

a match score processor (14) for generating a match score for each sound and each of one or more acoustic command models from the set of acoustic command models, each match score comprising an estimate of the closeness of a match between the acoustic command model and a series of feature signals corresponding to the sound;

characterized by

means (16) for outputting a recognition signal corresponding to the command model having the best match score for a current sound if the best match score for the current sound is better than a recognition threshold score for the current sound, the recognition threshold for the current sound comprising (a) a first confidence score if the best match score for a prior sound was better than a recognition threshold for that prior sound, or (b) a second confidence score better than the first confidence score if the best match score for a prior sound was worse than the recognition threshold for that prior sound.

2. A speech recognition apparatus as claimed in Claim 1, characterized in that the prior sound occurs immediately prior to the current sound.

3. A speech recognition apparatus as claimed in Claim 2, characterized in that:

the apparatus further comprises means (20) for storing at least one acoustic silence model representing one

or more series of acoustic feature values representing the absence of a spoken utterance;

the match score processor (10) generates a match score for each sound and the acoustic silence model, each match score comprising an estimate of the closeness of a match between the acoustic silence model and a series of feature signals corresponding to the sound; and

the recognition threshold for the current sound comprises the first confidence score (a1) if the match score for the prior sound and the acoustic silence model is better than a silence match threshold, and if the prior sound has a duration exceeding a silence duration threshold, or (a2) if the match score for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was better than a recognition threshold for that next prior sound, or (a3) if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was better than a recognition threshold for that prior sound; or

the recognition threshold for the current sound comprises the second confidence score better than the first confidence score (b1) if the match score for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was worse than the recognition threshold for that next prior sound, or (b2) if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was worse than the recognition threshold for that prior sound.

4. A speech recognition apparatus as claimed in Claim 3, characterized in that the recognition signal comprises a command signal for calling a program associated with the command.

5. A speech recognition apparatus as claimed in Claim 4, characterized in that:

the output means (16) comprises a display; and

the output means (16) displays one or more words corresponding to the command model having the best match score for a current sound if the best match score for the current sound is better than the recognition threshold score for the current sound.

6. A speech recognition apparatus as claimed in Claim 5, characterized in that the output means (16) outputs an unrecognizable-sound indication signal if the best match score for the current sound is worse than the recognition threshold score for the current sound.

7. A speech recognition apparatus as claimed in Claim 6, characterized in that the output means (16) displays anunrecognizable-sound indicator if the best match score for the current sound is worse than the recognition threshold score for the current sound.

8. A speech recognition apparatus as claimed in Claim 7, characterized in that unrecognizable-sound indicator comprises one or more question marks.

9. A speech recognition apparatus as claimed in Claim 1, characterized in that the acoustic processor (10) comprises a microphone (24).

10. A speech recognition apparatus as claimed in Claim 1, characterized in that:

each sound comprises a vocal sound; and

each command comprises at least one word.

11. A speech recognition method comprising the steps of:

measuring the value of at least one feature of each of a sequence of at least two sounds, the value of the fea-

ture of each sound being measured during each of a series of successive time intervals to produce a series of feature signals representing the feature values of the sound;

storing a set of acoustic command models, each acoustic command model representing one or more series of acoustic feature values representing an utterance of a command ssociated with the acoustic command model;

generating a match score for each sound and each of one or more acoustic command models from the set of acoustic command models, each match score comprising an estimate of the closeness of a match between the acoustic command model and a series of feature signals corresponding to the sound;
characterized by

outputting a recognition signal corresponding to the command model having the best match score for a current sound if the best match score for the current sound is better than a recognition threshold score for the current sound, the recognition threshold for the current sound comprising (a) a first confidence score if the best match score for a prior sound was better than a recognition threshold for that prior sound, or (b) a second confidence score better than the first confidence score if the best match score for a prior sound was worse than the recognition threshold for that prior sound.

12. A speech recognition method as claimed in Claim 11, characterized in that the prior sound occurs immediately prior to the current sound.

13. A speech recognition method as claimed in Claim 12, further comprising the steps of:

storing at least one acoustic silence model representing one or more series of acoustic feature values representing the absence of a spoken utterance;

generating a match score for each sound and the acoustic silence model, each match score comprising an estimate of the closeness of a match between the acoustic silence model and a series of feature signals corresponding to the sound; and characterized in that

the recognition threshold for the current sound comprises the first confidence score (a1) if the match score for the prior sound and the acoustic silence model is better than a silence match threshold, and if the prior sound has a duration exceeding a silence duration threshold, or (a2) if the match score for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was better than a recognition threshold for that next prior sound, or (a3) if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was better than a recognition threshold for that prior sound; or the recognition threshold for the current sound comprises the second confidence score better than the first confidence score (b1) if the match score for the prior sound and the acoustic silence model is better than the silence match threshold, and if the prior sound has a duration less than the silence duration threshold, and if the best match score for the next prior sound and an acoustic command model was worse than the recognition threshold for that next prior sound, or (b2) if the match score for the prior sound and the acoustic silence model is worse than the silence match threshold, and if the best match score for the prior sound and an acoustic command model was worse than the recognition threshold for that prior sound.

14. A speech recognition method as claimed in Claim 13, characterized in that the recognition signal comprises a command signal for calling a program associated with the command.

15. A speech recognition method as claimed in Claim 14, further comprising the step of displaying one or more words corresponding to the command model having the best match score for a current sound if the best match score for the current sound is better than the recognition threshold score for the current sound.

16. A speech recognition method as claimed in Claim 15, further comprising the step of outputting an unrecognizable-sound indication signal if the best match score for the current sound is worse than the recognition threshold score for the current sound.

17. A speech recognition method as claimed in Claim 16, further comprising the step of displaying an unrecognizable-

sound indicator if the best match score for the current sound is worse than the recognition threshold score for the current sound.

18. A speech recognition method as claimed in Claim 17, characterized in that unrecognizable-sound indicator comprises one or more question marks.

19. A speech recognition method as claimed in Claim 11, characterized in that:

each sound comprises a vocal sound; and

each command comprises at least one word.

Patentansprüche

1. Spracherkennungseinrichtung, die Folgendes umfasst:

einen Akustikprozessor (10) zum Messen des Wertes von mindestens einem Merkmal von jedem aus einer Folge von mindestens zwei Tönen, wobei der Akustikprozessor (10) den Wert des Merkmals jedes Tons während jedes aus einer Reihe aufeinanderfolgender Zeitintervalle misst, um eine Reihe von Merkmalsignalen zu erzeugen, die die Merkmalwerte des Tons darstellen;

Mittel (12) zum Speichern eines Satzes akustischer Befehlsmodelle, wobei jedes akustische Befehlsmodell eine oder mehrere Reihen akustischer Merkmalswerte darstellt, die eine Äußerung eines dem akustischen Befehlsmodell zugeordneten Befehls darstellen;

einen Vergleichswertprozessor (14) zum Erzeugen eines Vergleichswertes für jeden Ton und jedes von einem oder mehreren akustischen Befehlsmodellen aus dem Satz akustischer Befehlsmodelle, wobei jeder Vergleichswert eine Schätzung der Genauigkeit einer Übereinstimmung zwischen dem akustischen Befehlsmodell und einer Reihe dem Ton entsprechender Merkmalsignale umfasst;
gekennzeichnet durch:

Mittel (16) zum Ausgeben eines Erkennungssignals, das dem Befehlsmodell mit dem besten Vergleichswert für einen aktuellen Ton entspricht, falls der beste Vergleichswert für den aktuellen Ton besser als ein Erkennungsschwellenwert für den aktuellen Ton ist, wobei die Erkennungsschwelle für den aktuellen Ton Folgendes umfasst: (a) einen ersten Vertrauenswert, falls der beste Vergleichswert für einen früheren Ton besser als eine Erkennungsschwelle für diesen früheren Ton war, oder (b) einen zweiten Vertrauenswert, der besser als der erste Vertrauenswert ist, falls der beste Vergleichswert für einen früheren Ton schlechter als die Erkennungsschwelle für diesen früheren Ton war.

2. Spracherkennungsvorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass der frühere Ton unmittelbar vor dem aktuellen Ton auftritt.

3. Spracherkennungsvorrichtung nach Anspruch 2, dadurch gekennzeichnet, dass:

die Vorrichtung außerdem Mittel (20) zum Speichern von mindestens einem akustischen Schweigemodell umfasst, das eine oder mehrere Reihen akustischer Merkmalswerte darstellt, die das Nichtvorhandensein einer gesprochenen Äußerung darstellen;

der Vergleichswertprozessor (10) für jeden Ton und das akustische Schweigemodell einen Vergleichswert erzeugt, wobei jeder Vergleichswert eine Schätzung der Genauigkeit einer Übereinstimmung zwischen dem akustischen Schweigemodell und einer Reihe von dem Ton entsprechenden Merkmalsignalen umfasst; und

die Erkennungsschwelle für den aktuellen Ton den ersten Vertrauenswert umfasst, (a1) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell besser als eine Schweigevergleichsschwelle ist und falls der frühere Ton eine Dauer aufweist, die eine Schweigedauerschwelle übersteigt, oder (a2) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell besser als die Schweigevergleichsschwelle ist und falls der frühere Ton eine Dauer hat, die kürzer als die Schweigedauerschwelle ist und falls der beste Vergleichswert für den nächsten früheren Ton und ein akustisches Befehlsmodell besser als eine Erken-

nungsschwelle für diesen nächsten früheren Ton war, oder (a3) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell schlechter als die Schweigevergleichsschwelle ist und falls der beste Vergleichswert für den früheren Ton und ein akustisches Befehlsmodell besser als eine Erkennungsschwelle für diesen früheren Ton war; oder

dass die Erkennungsschwelle für den aktuellen Ton den zweiten Vertrauenswert umfasst, der besser als der erste Vertrauenswert ist, (b1) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell besser als die Schweigevergleichsschwelle ist und falls der frühere Ton eine Dauer hat, die kürzer als die Schweigedauerschwelle ist, und falls der beste Vergleichswert für den nächsten früheren Ton und ein akustisches Befehlsmodell schlechter als die Erkennungsschwelle für diesen nächsten früheren Ton war, oder (b2) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell schlechter als die Schweigevergleichsschwelle ist und falls der beste Vergleichswert für den früheren Ton und ein akustisches Befehlsmodell schlechter als die Erkennungsschwelle für diesen früheren Ton war.

4. Spracherkennungsvorrichtung nach Anspruch 3, dadurch gekennzeichnet, dass das Erkennungssignal ein Befehlssignal zum Aufrufen eines dem Befehl zugeordneten Programms umfasst.

5. Spracherkennungsvorrichtung nach Anspruch 4, dadurch gekennzeichnet, dass:

das Ausgabemittel (16) eine Anzeige umfasst; und

das Ausgabemittel (16) eines oder mehrere Worte anzeigt, die dem Befehlsmodell mit dem besten Vergleichswert für einen aktuellen Ton entsprechen, falls der beste Vergleichswert für den aktuellen Ton besser als der Erkennungsschwellenwert für den aktuellen Ton ist.

6. Spracherkennungsvorrichtung nach Anspruch 5, dadurch gekennzeichnet, dass das Ausgabemittel (16) ein Anzeigesignal für einen nicht erkennbaren Ton ausgibt, falls der beste Vergleichswert für den aktuellen Ton schlechter als der Erkennungsschwellenwert für den aktuellen Ton ist.

7. Spracherkennungsvorrichtung nach Anspruch 6, dadurch gekennzeichnet, dass das Ausgabemittel (16) eine Anzeige für einen nicht erkennbaren Ton anzeigt, falls der beste Vergleichswert für den aktuellen Ton schlechter als der Erkennungsschwellenwert für den aktuellen Ton ist.

8. Spracherkennungsvorrichtung nach Anspruch 7, dadurch gekennzeichnet, dass die Anzeige für einen nicht erkennbaren Ton ein oder mehrere Fragezeichen umfasst.

9. Spracherkennungsvorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass der Akustikprozessor (10) ein Mikrofon (24) umfasst.

10. Spracherkennungsvorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass:

jeder Ton einen Vokalton umfasst; und

jeder Befehl mindestens ein Wort umfasst.

11. Spracherkennungsverfahren, das die folgenden Schritte umfasst:

Messen des Wertes von mindestens einem Merkmal von jedem aus einer Folge von mindestens zwei Tönen, wobei der Wert des Merkmals jedes Tons während jeder aus einer Reihe aufeinanderfolgender Zeitintervalle gemessen wird, um eine Reihe von Merkmalsignalen zu erzeugen, die die Merkmalwerte des Tons darstellen;

Speichern eines Satzes akustischer Befehlsmodelle, wobei jedes akustische Befehlsmodell eine oder mehrere Reihen akustischer Merkmalswerte darstellt, die eine Äußerung eines dem akustischen Befehlsmodell zugeordneten Befehls darstellen; Erzeugen eines Vergleichswertes für jeden Ton und jedes von einem oder mehreren akustischen Befehlsmodellen aus dem Satz akustischer Befehlsmodelle, wobei jeder Vergleichswert eine Schätzung der Genauigkeit einer Übereinstimmung zwischen dem akustischen Befehlsmodell und einer Reihe dem Ton entsprechender Merkmalsignale umfasst;
gekennzeichnet durch

das Ausgeben eines Erkennungssignals, das dem Befehlsmodell mit dem besten Vergleichswert für einen aktuellen Ton entspricht, falls der beste Vergleichswert für den aktuellen Ton besser als ein Erkennungsschwellenwert für den aktuellen Ton ist, wobei die Erkennungsschwelle für den aktuellen Ton Folgendes umfasst: (a) ein erster Vertrauenswert, falls der beste Vergleichswert für einen früheren Ton besser als eine Erkennungsschwelle für diesen früheren Ton war, oder (b) ein zweiter Vertrauenswert, der besser als der erste Vertrauenswert ist, falls der beste Vergleichswert für einen früheren Ton schlechter als die Erkennungsschwelle für diesen früheren Ton war.

12. Spracherkennungsverfahren nach Anspruch 11, dadurch gekennzeichnet, dass der frühere Ton unmittelbar vor dem aktuellen Ton auftritt.

13. Spracherkennungsverfahren nach Anspruch 12, das außerdem die folgenden Schritte umfasst:

Speichern von mindestens einem akustischen Schweigemodell, das eine oder mehrere Reihen akustischer Merkmalswerte darstellt, die das Nichtvorhandensein einer gesprochenen Äußerung darstellen;

Erzeugen eines Vergleichswertes für jeden Ton und das akustische Schweigemodell, wobei jeder Vergleichswert eine Schätzung der Genauigkeit einer Übereinstimmung zwischen dem akustischen Schweigemodell und einer Reihe von dem Ton entsprechenden Merkmalsignalen umfasst; und das dadurch gekennzeichnet ist, dass

die Erkennungsschwelle für den aktuellen Ton den ersten Vertrauenswert umfasst, (a1) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell besser als eine Schweigevergleichsschwelle ist und falls der frühere Ton eine Dauer aufweist, die eine Schweigedauerschwelle übersteigt, oder (a2) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell besser als die Schweigevergleichsschwelle ist und falls der frühere Ton eine Dauer hat, die kürzer als die Schweigedauerschwelle ist und falls der beste Vergleichswert für den nächsten früheren Ton und ein akustisches Befehlsmodell besser als eine Erkennungsschwelle für diesen nächsten früheren Ton war, oder (a3) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell schlechter als die Schweigevergleichsschwelle ist und falls der beste Vergleichswert für den früheren Ton und ein akustisches Befehlsmodell besser als eine Erkennungsschwelle für diesen früheren Ton war; oder dass die Erkennungsschwelle für den aktuellen Ton den zweiten Vertrauenswert umfasst, der besser als der erste Vertrauenswert ist, (b1) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell besser als die Schweigevergleichsschwelle ist und falls der frühere Ton eine Dauer hat, die kürzer als die Schweigedauerschwelle ist, und falls der beste Vergleichswert für den nächsten früheren Ton und ein akustisches Befehlsmodell schlechter als die Erkennungsschwelle für diesen nächsten früheren Ton war, oder (b2) falls der Vergleichswert für den früheren Ton und das akustische Schweigemodell schlechter als die Schweigevergleichsschwelle ist und falls der beste Vergleichswert für den früheren Ton und ein akustisches Befehlsmodell schlechter als die Erkennungsschwelle für diesen früheren Ton war.

14. Spracherkennungsverfahren nach Anspruch 13, dadurch gekennzeichnet, dass das Erkennungssignal ein Befehlssignal zum Aufrufen eines dem Befehl zugeordneten Programms umfasst.

15. Spracherkennungsverfahren nach Anspruch 14, das außerdem den Schritt des Anzeigens eines oder mehrerer Worte umfasst, die dem Befehlsmodell mit dem besten Vergleichswert für einen aktuellen Ton entsprechen, falls der beste Vergleichswert für den aktuellen Ton besser als der Erkennungsschwellenwert für den aktuellen Ton ist.

16. Spracherkennungsverfahren nach Anspruch 15, das außerdem den Schritt des Ausgebens eines Anzeigesignals für einen nicht erkennbaren Ton umfasst, falls der beste Vergleichswert für den aktuellen Ton schlechter als der Erkennungsschwellenwert für den aktuellen Ton ist.

17. Spracherkennungsverfahren nach Anspruch 16, das außerdem den Schritt des Anzeigens einer Anzeige für einen nicht erkennbaren Ton umfasst, falls der beste Vergleichswert für den aktuellen Ton schlechter als der Erkennungsschwellenwert für den aktuellen Ton ist.

18. Spracherkennungsverfahren nach Anspruch 17, dadurch gekennzeichnet, dass die Anzeige für einen nicht erkennbaren Ton eines oder mehrere Fragezeichen umfasst.

19. Spracherkennungsverfahren nach Anspruch 11, dadurch gekennzeichnet, dass

jeder Ton einen Vokalton umfasst; und

jeder Befehl mindestens ein Wort umfasst.

Revendications

1. Appareil de reconnaissance de la parole comprenant :

un processeur acoustique (10) pour mesurer la valeur d'au moins une caractéristique de chaque son d'une séquence d'au moins deux sons, ledit processeur acoustique (10) mesurant la valeur de la caractéristique de chaque son pendant chacun des intervalles d'une suite d'intervalles de temps successifs pour produire une suite de signaux de caractéristique représentant les valeurs des caractéristiques du son ;

un moyen (12) pour enregistrer un ensemble de modèles de commande acoustique, chaque modèle de commande acoustique représentant une ou plusieurs séries de valeurs de caractéristiques acoustiques représentant un énoncé d'une commande associé au modèle de commande acoustique ;

un processeur de résultat de concordance (14) pour créer un résultat de concordance pour chaque son et chaque modèle parmi un ou plusieurs modèle de commande acoustique à partir de l'ensemble des modèles de commandes acoustiques, chaque résultat de concordance comprenant une estimation du rapport de concordance entre le modèle de commande acoustique et une suite de signaux de caractéristique correspondant au son ;
caractérisé par

un moyen (16) pour sortir un signal de reconnaissance correspondant au modèle de commande ayant le meilleur score de concordance pour un son courant si le meilleur résultat de concordance pour le son courant est meilleur qu'un score du seuil de reconnaissance pour le son courant, le seuil de reconnaissance pour le son courant comprenant (a) un premier score de fiabilité si le meilleur résultat de concordance pour un son antérieur était supérieur à un seuil de reconnaissance pour ce son antérieur, ou (b) un deuxième score de fiabilité meilleur que le premier score de fiabilité si le meilleur résultat de concordance pour un son antérieur était inférieur au seuil de reconnaissance de ce son antérieur.

2. Appareil pour la reconnaissance de la parole selon la revendication 1, caractérisé en ce que le son antérieur précède immédiatement le son courant.

3. Appareil de reconnaissance de la parole selon la revendication 2, caractérisé en ce que :

l'appareil comprend en outre un moyen (20) pour enregistrer au moins un modèle acoustique de silence représentant une ou plusieurs séries de valeurs de caractéristique acoustique représentant l'absence de tout énoncé parlé ;

le processeur de résultat de concordance (10) génère un résultat de concordance pour chaque son et le modèle de silence acoustique, chaque score de concordance comprenant une estimation du rapport de concordance entre le modèle acoustique de silence et une suite de signaux de caractéristiques correspondant au son ; et

le seuil de reconnaissance pour le son courant comprend un premier résultat de fiabilité (a1) si le score de concordance pour le son antérieur et le modèle de silence acoustique et meilleur qu'un seuil de concordance de silence, et si le son antérieur a une durée dépassant le seuil de la durée du silence, ou (a2) si le score de concordance pour le son antérieur et le modèle de silence acoustique est supérieur au seuil de concordance du silence, et si le son antérieur a une durée inférieure à celle du seuil de silence, et si le meilleur résultat de concordance pour le son antérieur suivant et un modèle de commande acoustique était meilleur qu'un seuil de reconnaissance pour ce son antérieur suivant, ou (a3) si le score de concordance du son antérieur et du modèle de silence acoustique était inférieur au seuil de concordance du silence, et si le meilleur score de concordance pour le son antérieur et un modèle de commande acoustique était supérieur à un seuil de reconnaissance pour ce son antérieur ; ou

le seuil de reconnaissance pour le son courant comprend un deuxième score de fiabilité meilleur que le pre-

mier score de fiabilité (b1) si le score de concordance pour le son antérieur et le modèle de silence acoustique est supérieur au seuil de concordance du silence, et si le son antérieur a une durée inférieure au seuil de la durée du silence, et si le meilleur résultat de concordance pour le son antérieur suivant et un modèle de commande acoustique était moins bon que le seuil de reconnaissance de ce son antérieur, ou (b2) si le score de concordance pour le son antérieur et le modèle de silence acoustique était inférieur au seuil de concordance du silence, et si le meilleur résultat de concordance pour le son antérieur et un modèle de commande acoustique était inférieur au seuil de reconnaissance pour ce son antérieur.

4. Appareil de reconnaissance de la parole selon la revendication 3, caractérisé en ce que le signai de reconnaissance comprend un signal de commande pour appeler un programme associé à la commande.

5. Appareil pour la reconnaissance de la parole selon la revendication 4, caractérisé en ce que :

le moyen de sortie (16) comprend un écran ; et

le moyen de sortie (16) affiche un ou plusieurs mots correspondant au modèle de commande ayant le meilleur score de concordance pour un mot courant si le meilleur résultat de concordance pour le son courant est meilleur que le résultat du seuil de reconnaissance pour le mot courant.

6. Appareil pour la reconnaissance de la parole selon la revendication 5, caractérisé en ce que le moyen de sortie (16) sort un signal indiquant qu'un son n'est pas reconnaissable si le meilleur score de concordance pour le son courant est inférieur au score du seuil de reconnaissance pour le mot courant.

7. Appareil pour la reconnaissance de la parole selon la revendication 6, caractérisé en ce que le moyen de sortie (16) affiche un indicateur indiquant qu'un son n'est pas reconnaissable si le meilleur score de concordance pour le son courant est inférieur au score du seuil de reconnaissance pour le mot courant.

8. Appareil pour la reconnaissance de la parole selon la revendication 7,caractérisé en ce que l'indicateur de son non reconnaissable comprend un ou plusieurs point d'interrogation.

9. Appareil de reconnaissance de la parole selon la revendication 1, caractérisé en ce que le processeur acoustique (10) comprend un microphone (24).

10. Appareil pour la reconnaissance de la parole selon la revendication 1 caractérisé en ce que :

chaque son comprend un son vocal ; et

chaque commande comprend au moins un mot.

11. Méthode de reconnaissance de la parole comprenant les phases qui consistent à:

mesurer la valeur d'au moins une caractéristique de chaque son d'une séquence d'au moins deux sons, la valeur de la caractéristique de chaque son étant mesurée pendant chaque intervalle d'une suite d'intervalles de temps successifs pour produire une suite de signaux de caractéristiques représentant les valeurs des caractéristiques du son ;

enregistrer un ensemble de modèles de commandes acoustiques, chaque modèle de commande acoustique représentant une ou plusieurs séries de valeurs de caractéristiques acoustiques représentant un énoncé d'une commande associé au modèle de commande acoustique ;

créer un résultat de concordance pour chaque son et chaque modèle parmi un ou plusieurs modèles de commande acoustiques à partir de l'ensemble des modèles de commandes acoustiques, chaque résultat de concordance comprenant une estimation du rapport de concordance entre le modèle de commande acoustique et une suite de signaux de caractéristique correspondant au son ;
caractérisée par

la sortie d'un signal de reconnaissance correspondant au modèle de commande ayant le meilleur score de concordance pour un son courant si le meilleur résultat de concordance pour le son courant est meilleur que

le score du seuil de reconnaissance pour le son courant, le seuil de reconnaissance pour le son courant comprenant (a) un premier score de fiabilité si le meilleur résultat de concordance pour un son antérieur était supérieur à un seuil de reconnaissance pour ce son antérieur, ou (b) un deuxième score de fiabilité meilleur que le premier score de fiabilité si le meilleur résultat de concordance pour un son antérieur était inférieur au seuil de reconnaissance de ce son antérieur.

12. Méthode pour la reconnaissance de la parole selon la revendication 11, caractérisée en ce que le son antérieur précède immédiatement le son courant.

13. Méthode de reconnaissance de la parole selon la revendication 12, comprenant en outre les phases qui consistent à :

enregistrer au moins un modèle acoustique de silence représentant une ou plusieurs séries de valeurs de caractéristiques acoustiques représentant l'absence de tout énoncé parlé ;

générer un résultat de concordance pour chaque son et le modèle de silence acoustique, chaque score de concordance comprenant une estimation du rapport de concordance entre le modèle acoustique du silence et une suite de signaux de caractéristiques correspondant au son ; et caractérisée en ce que

le seuil de reconnaissance pour le son courant comprend un premier résultat de fiabilité (a1) si le score de concordance pour le son antérieur et le modèle du silence acoustique est meilleur qu'un seuil de concordance de silence, et si le son antérieur a une durée dépassant le seuil de la durée du silence, ou (a2) si le score de concordance pour le son antérieur et le modèle du silence acoustique est supérieur au seuil de concordance du silence, et si le son antérieur a une durée inférieure à celle du seuil de silence, et si le meilleur résultat de concordance pour le son antérieur suivant et un modèle de commande acoustique était meilleur qu'un seuil de reconnaissance pour ce son antérieur suivant, ou (a3) si le score de concordance du son antérieur et du modèle de silence acoustique était inférieur au seuil de concordance du silence, et si le meilleur score de concordance pour le son antérieur et un modèle de commande acoustique était supérieur à un seuil de reconnaissance pour ce son antérieur ; ou le seuil de reconnaissance pour le son courant comprend un deuxième score de fiabilité meilleur que le premier score de fiabilité (b1) si le score de concordance pour le son antérieur et le modèle du silence acoustique est supérieur au seuil de concordance du silence, et si le son antérieur a une durée inférieure au seuil de la durée du silence, et si le meilleur résultat de concordance pour le son antérieur suivant et un modèle de commande acoustique était moins bon que le seuil de reconnaissance de ce son antérieur, ou (b2) si le score de concordance pour le son antérieur et le modèle de silence acoustique était inférieur au seuil de concordance du silence, et si le meilleur résultat de concordance pour le son antérieur et un modèle de commande acoustique était inférieur au seuil de reconnaissance pour ce son antérieur.

14. Méthode de reconnaissance de la parole selon la revendication 13, caractérisée en ce que le signal de reconnaissance comprend un signai de commande pour appeler un programme associé à la commande.

15. Méthode pour la reconnaissance de la parole selon la revendication 14, comprenant en outre la phase qui consiste à afficher un ou plusieurs mots correspondant au modèle de commande ayant le meilleur score de concordance pour un mot courant si le meilleur résultat de concordance pour le son courant est supérieur au score du seuil de reconnaissance pour le mot courant.

16. Méthode pour la reconnaissance de la parole selon la revendication 15, comprenant en outre la phase qui consiste à émettre un signal indiquant qu'un son n'est pas reconnaissable si le meilleur score de concordance pour le son courant est inférieur au score du seuil de reconnaissance pour le mot courant.

17. Méthode pour la reconnaissance de la parole selon la revendication 16, comprenant en outre la phase qui consiste à afficher un indicateur indiquant qu'un son n'est pas reconnaissable si le meilleur score de concordance pour le son courant est inférieur au score du seuil de reconnaissance pour le mot courant.

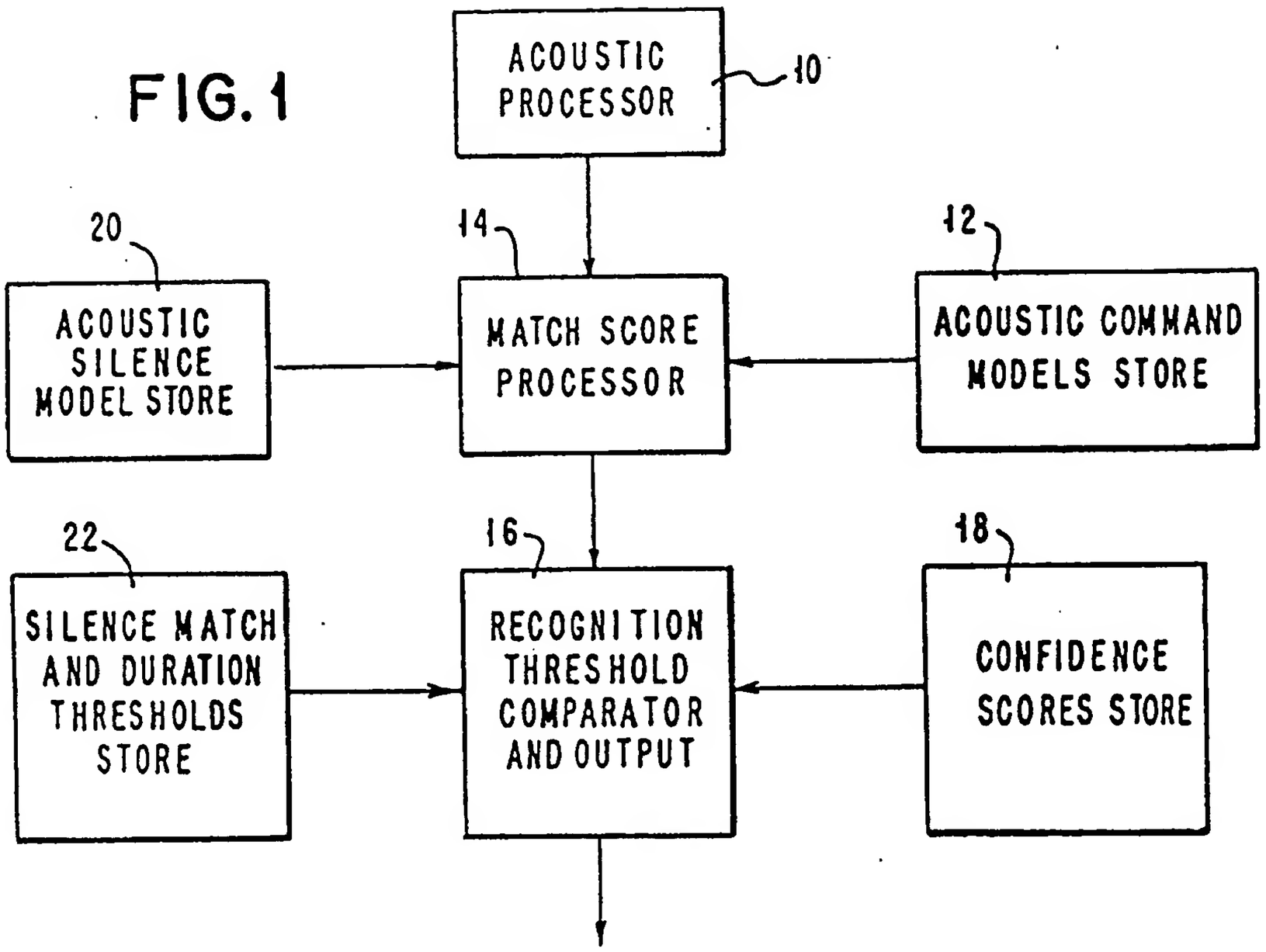
18. Méthode pour la reconnaissance de la parole selon la revendication 17,caractérisée en ce que l'indicateur de son non reconnaissable comprend un ou plusieurs point d'interrogation.

19. Méthode pour la reconnaissance de la parole selon la revendication 11, caractérisée en ce que :

chaque son comprend un son vocal ; et

chaque commande comprend au moins un mot.

FIG. 1


ACOUSTIC PROCESSOR
10
20
ACOUSTIC SILENCE MODEL STORE
14
MATCH SCORE PROCESSOR
12
ACOUSTIC COMMAND MODELS STORE
22
SILENCE MATCH AND DURATION THRESHOLDS STORE
16
RECOGNITION THRESHOLD COMPARATOR AND OUTPUT
18
CONFIDENCE SCORES STORE

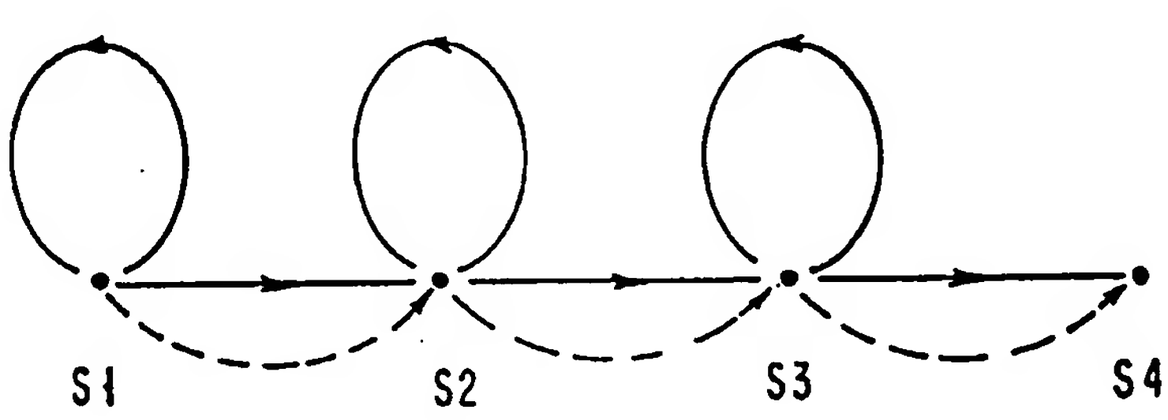

S1
S2
S3
S4

FIG. 2

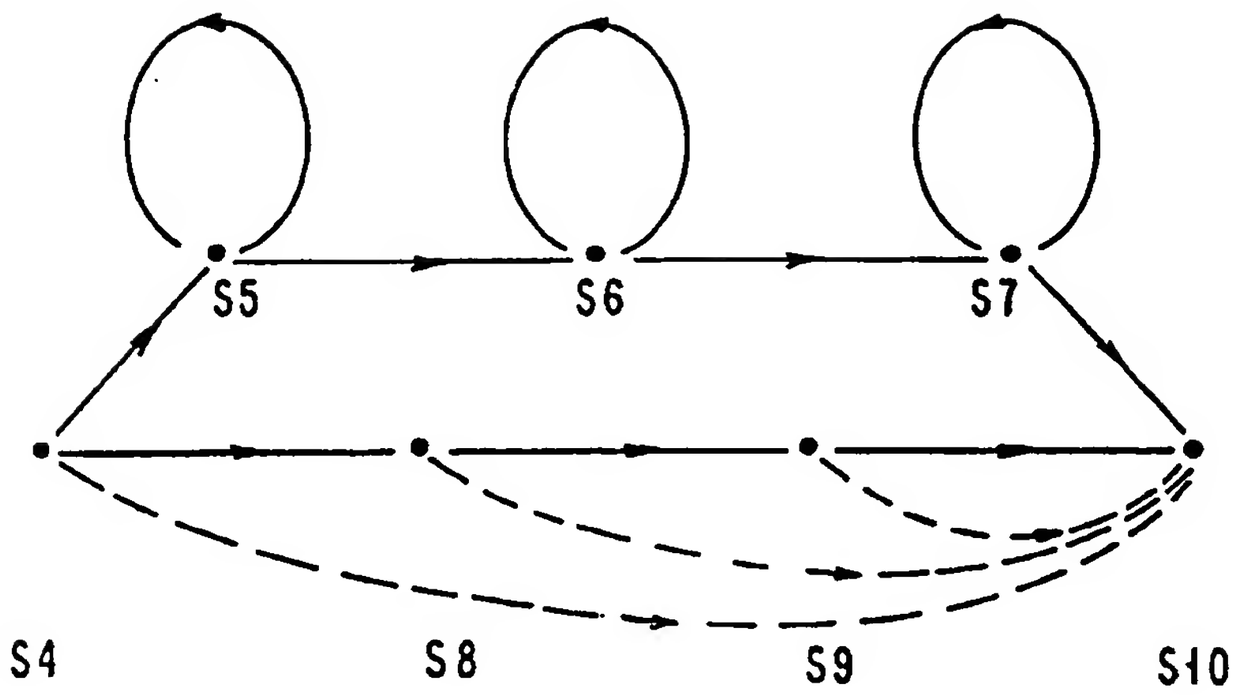


FIG. 3

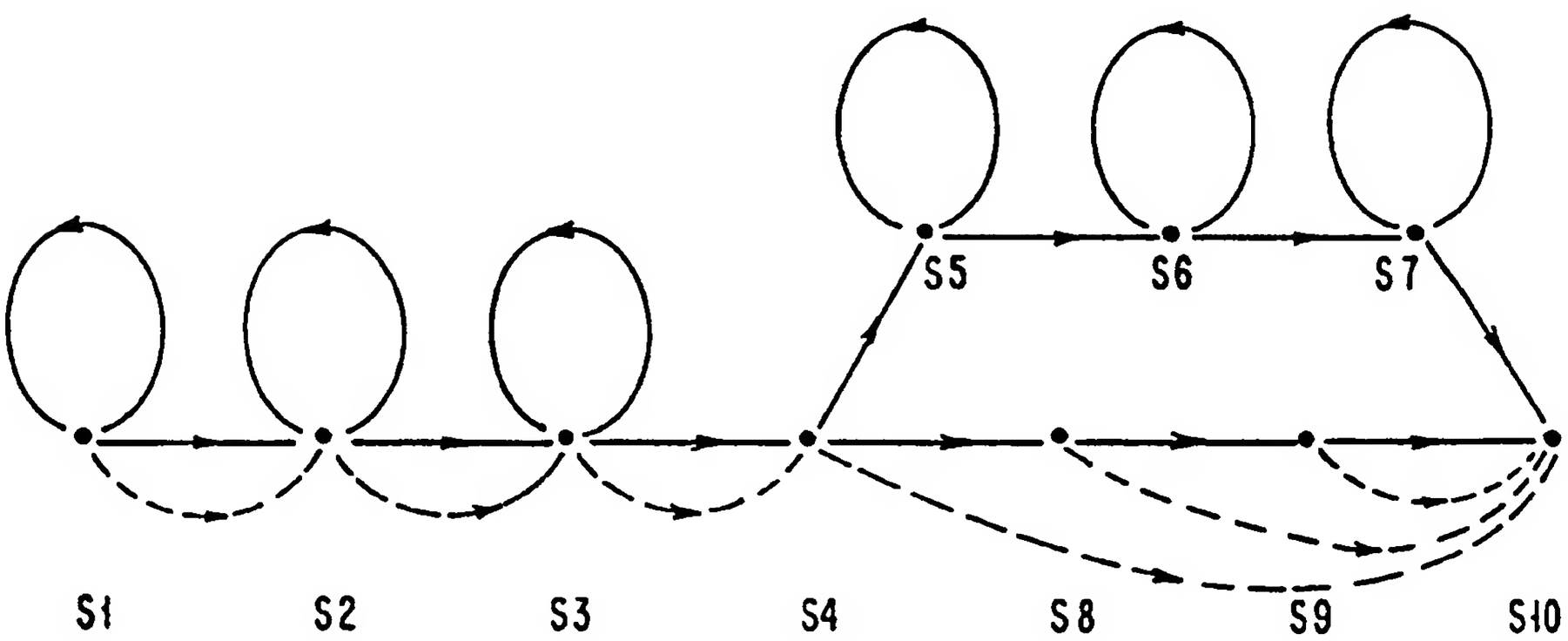


FIG. 4

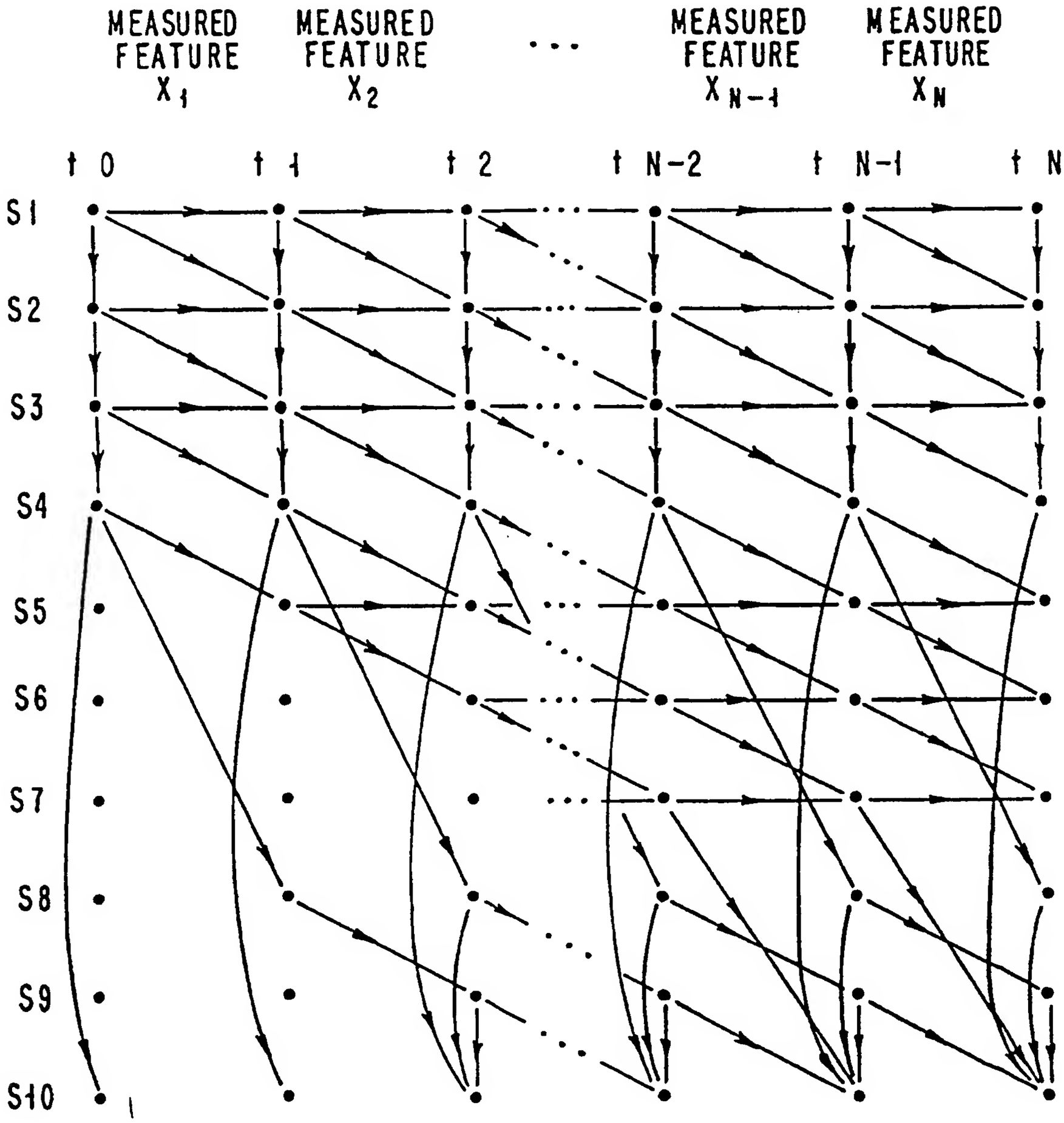

MEASURED FEATURE X_1
MEASURED FEATURE X_2
MEASURED FEATURE X_{N-1}
MEASURED FEATURE X_N
t 0
t 1
t 2
t N-2
t N-1
t N
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10

FIG. 5

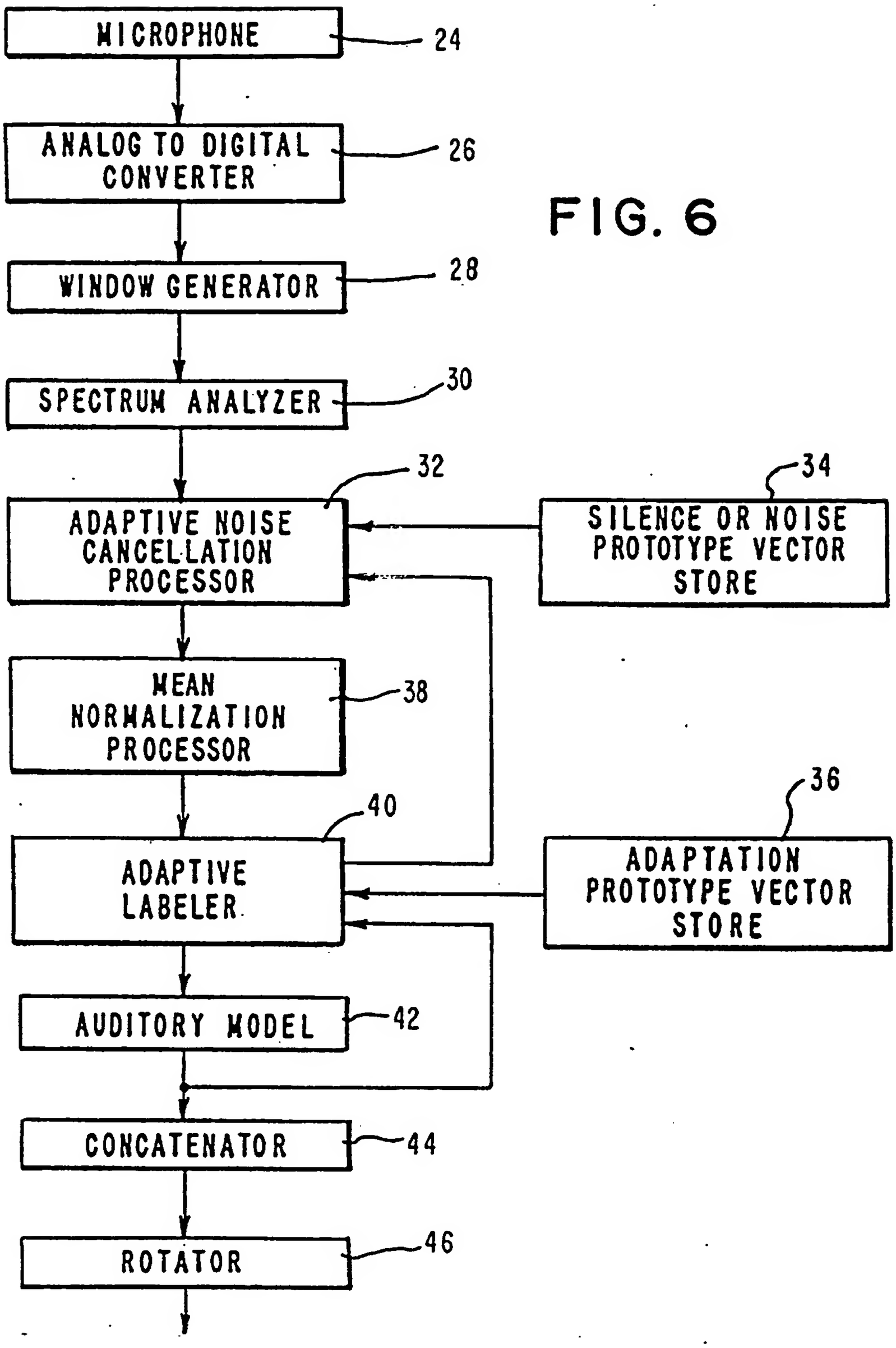

MICROPHONE
24
ANALOG TO DIGITAL CONVERTER
26
WINDOW GENERATOR
28
SPECTRUM ANALYZER
30
ADAPTIVE NOISE CANCELLATION PROCESSOR
32
SILENCE OR NOISE PROTOTYPE VECTOR STORE
34
MEAN NORMALIZATION PROCESSOR
38
ADAPTIVE LABELER
40
ADAPTATION PROTOTYPE VECTOR STORE
36
AUDITORY MODEL
42
CONCATENATOR
44
ROTATOR
46

FIG. 6

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